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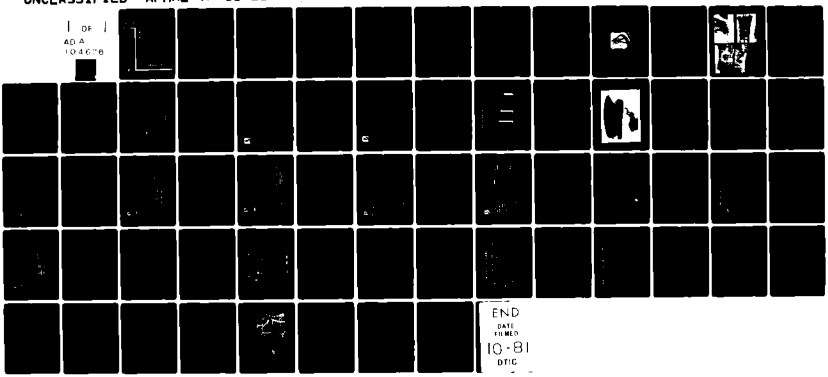

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IMAGE GENERATION/DISPLAY CONFERENCE II, 10-12 June 1981: CLOSING COMMENTS

By

Earl A. Alluisi

Chief Scientist
Air Force Human Resources Laboratory
Brooks Air Force Base, Texas 78235

July 1981

Final Report

A

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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This report has been reviewed and is approved for publication.

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Vice Commander

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combat mission training (CMT)	impact analysis	visual displays
computer image generation (CIG)	instructor/operator station	visual simulation
flight simulation	low-level flight	weapons delivery training
flying training	threat simulation	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

These were the closing comments made by the Chief Scientist of the Air Force Human Resources Laboratory (AFHRL) at the 1981 Image Generation/Display Conference II on 10-12 June 1981 in Phoenix, Arizona, sponsored by the Laboratory's Operations Training Division.

The paper briefly outlines the objectives and accomplishments of the conference and acknowledges the contributions of some specific individuals.

The paper then addresses the state-of-the-art in image generation/display for flight simulation, which was the substantive area of the conference. In this regard, the paper discusses the AFHRL Advanced Simulator for Pilot

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Item 20 (Continued):

Training (ASPT), its history, and its application to specific training areas such as conventional dive bomb tasks and low-angle strafe, using the A-10 configuration of the ASPT. Some experimental results are reported. Research and development (R&D) on the ASPT is now advancing to air combat mission training (CMT). The paper describes what is involved in realizing state-of-the-art CMT; namely, (1) a data base collection system, (2) an image generation system, and (3) a crew interface/display system. The status of AFHRL R&D in each of these areas is presented.

Finally, the need for addressing real and potential impacts of successful R&D in credible, quantitative terms is emphasized. A "notional" CMT impact analysis is provided to show how R&D organizations can present options to Air Force management—options through which they can increase the ease and probability of air combat success.

AFHRL-Technical Paper-81-28 July 1981

IMAGE GENERATION/DISPLAY CONFERENCE II, 10-12 June 1981: CLOSING COMMENTS

By

Earl A. Alluisi

Chief Scientist
Air Force Human Resources Laboratory
Brooks Air Force Base, Texas 78235

Briefing Presented at the 1981 Image Generation/Display Conference II, Phoenix, Arizona, 10-12 June 1981.

A

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IMAGE GENERATION/DISPLAY CONFERENCE II,
10-12 June 1981:
CLOSING COMMENTS

I. OVERVIEW

It is both an honor and a pleasure for me to be able to make a few closing comments at this, The 1981 Image Generation/Display Conference II. I shall limit my comments to three areas as follows:

1. The *conference* itself, and those who organized and participated in it.

2. The *state-of-the-art* in image generation/display for flight simulation, the substantive area of the conference.

3. The *impacts*, real or potential, and the need to address them—to show what difference it might make were we to be successful in our research and development (R&D) efforts.

II. THE CONFERENCE

A. OBJECTIVES MET

The 1981 Image Generation/Display Conference II is the second AFHRL-sponsored conference on the development and use of imagery generated and displayed for visual flight simulation. The first conference was held 4 years ago—in May 1977—at Williams Air Force Base. The conference objective was to cover *both* out-of-cockpit and sensor visual flight simulation, thereby providing a state-of-the-art review of the entire area. The conference has now been held, and it did what it purported to do—it provided a state-of-the-art review of image generation and display for visual flight simulation.

B. ACKNOWLEDGEMENTS AND THANKS

The Air Force Human Resources Laboratory (AFHRL) is proud and pleased to have been able to sponsor IMAGE-II.

We are pleased to acknowledge the contributions of, and to thank, those who so successfully organized the conference; namely, the personnel of the Operations Training Division (AFHRL/OT) as listed on pages 3 and 4 of the program brochure and in the conference *Proceedings*—especially, Colonel Dick Needham (AFHRL/OT Division Chief), Eric Monroe (Conference Chairman), Audrey Vasenko (Conference Secretary), and Lieutenant Caroline Hanson (Conference Treasurer).

Likewise, we are pleased to acknowledge the stimulating and often provocative contributions of the outstanding scientists and engineers who served as Session Chairmen: Bernie Kulp (Chief Scientist, Office of the Director of Laboratories, Air Force Systems Command), Captain Rush (Assistant Chief of Staff for Flight Training, Office of the Chief of Naval Education and Training), Lieutenant Colonel Adams (Chief, Aviation Systems, PM-TRADE), John Sinacori (President, Sinacori Associates), Con Kraft (Chief Scientist, Crew Systems, Boeing Aerospace Company), Harry Snyder (Professor, Virginia Polytechnic Institute and State University) and Ralph Haber (Professor, University of Illinois at Chicago Circle), Colonel Lopina (Deputy for Engineering, Aeronautical Systems Division) who was unable to attend because of a late-rising command requirement and Colonel Puhlam (Chief, Training Devices, Systems Management Division, Ogden Air Logistics Center) who substituted so well for him, and Bob Howe (Professor, University of Michigan) who also serves as chairman of the AFHRL/OT Research Advisory Panel.

Finally, but certainly not least, we are pleased to acknowledge with thanks the contributions of those who really made this a conference—the *participants*, from Kent Stevens of MIT who presented the first paper in the first session, down through Dennis Breglia of NTEC who presented Dorothy Baldwin's paper at the end of the final session.

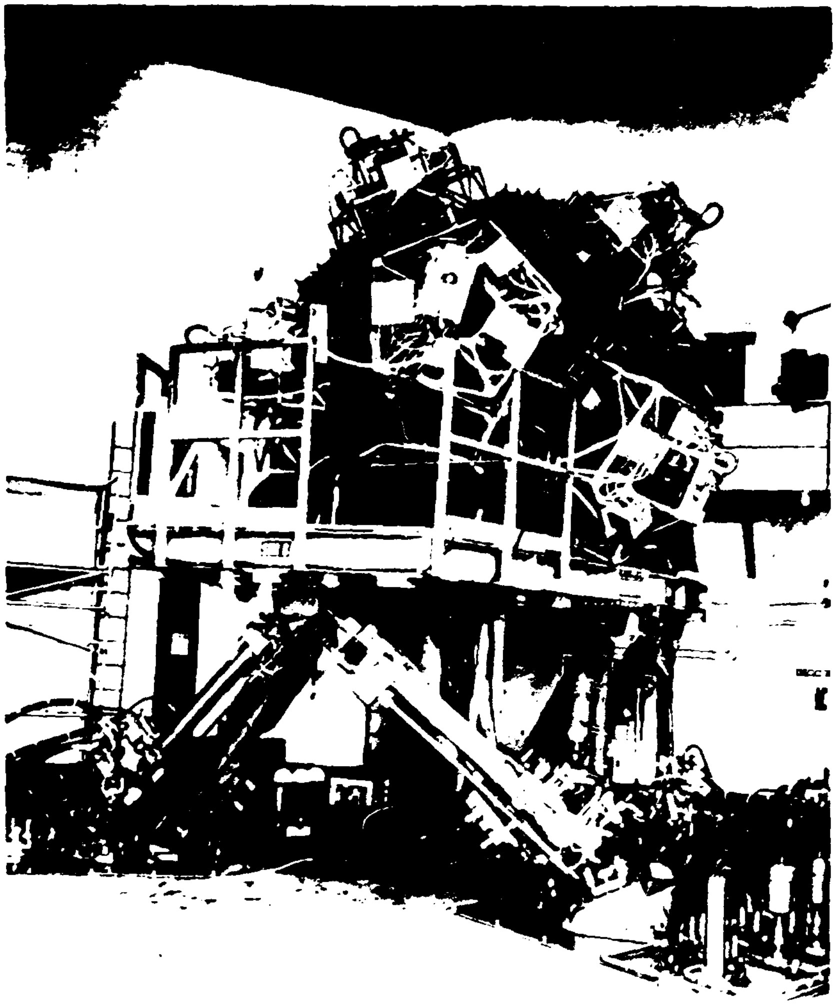
I would like to ask you to join me in applauding these contributions and in thanking the contributors for having made this "IMAGE-II" conference the successful experience it has been for all of us.

(APPLAUSE)

AF HUMAN RESOURCES LABORATORY

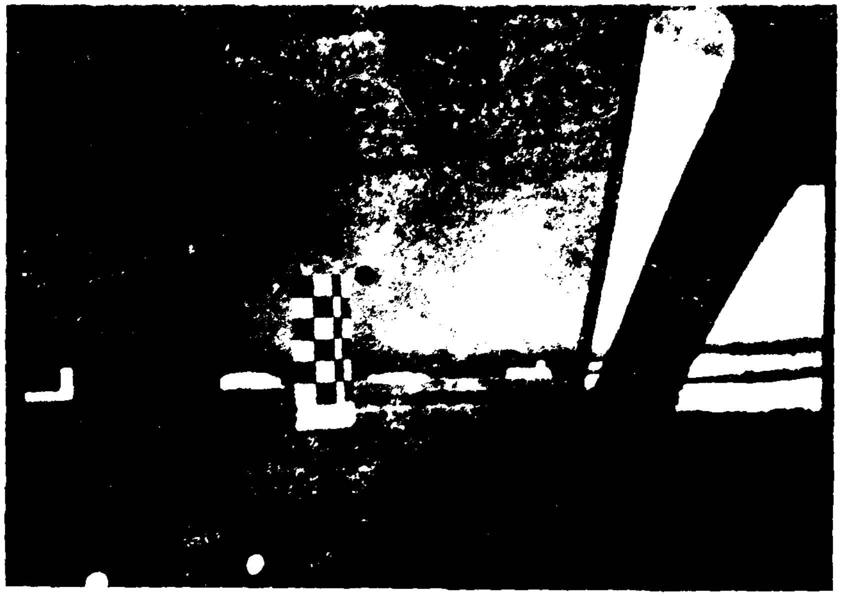
III. THE STATE-OF-THE-ART

The *Advanced Simulator for Undergraduate Pilot Training (ASUPT)* was the state-of-the-art embodiment of image generation and display for visual flight simulation circa the mid-1970s. It included a T-37 cockpit and a seven-channel visual display system mounted on a six-degrees-of-freedom motion platform. The visual display was a cathode ray tube (CRT) mosaic with computer image generation (CIG). The instructor/operator station (IOS) was the latest and most complete of its kind.

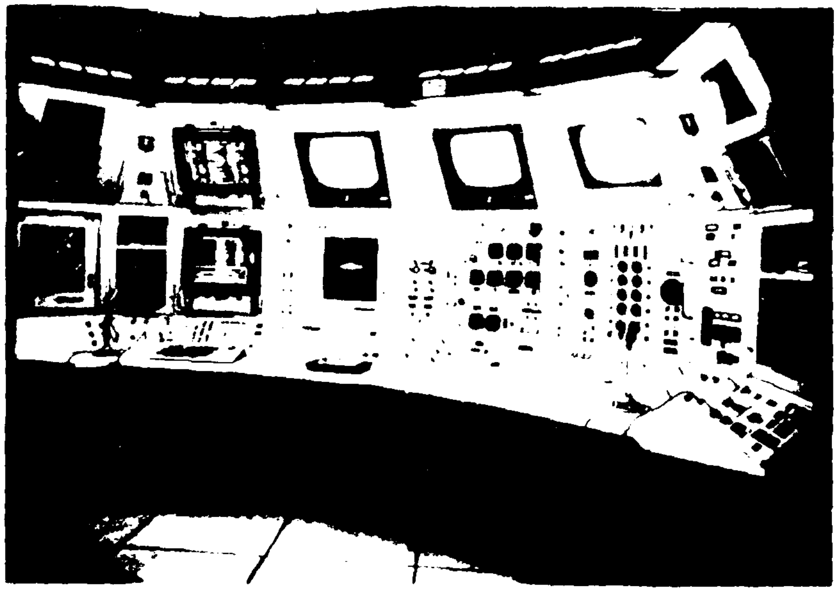


ADVANCED SIMULATOR FOR PILOT TRAINING
(ASPT)

T-37 COCKPIT AND 7-CHANNEL VISUAL DISPLAY MOUNTED ON SIX DEGREE-OF-FREEDOM MOTION PLATFORM



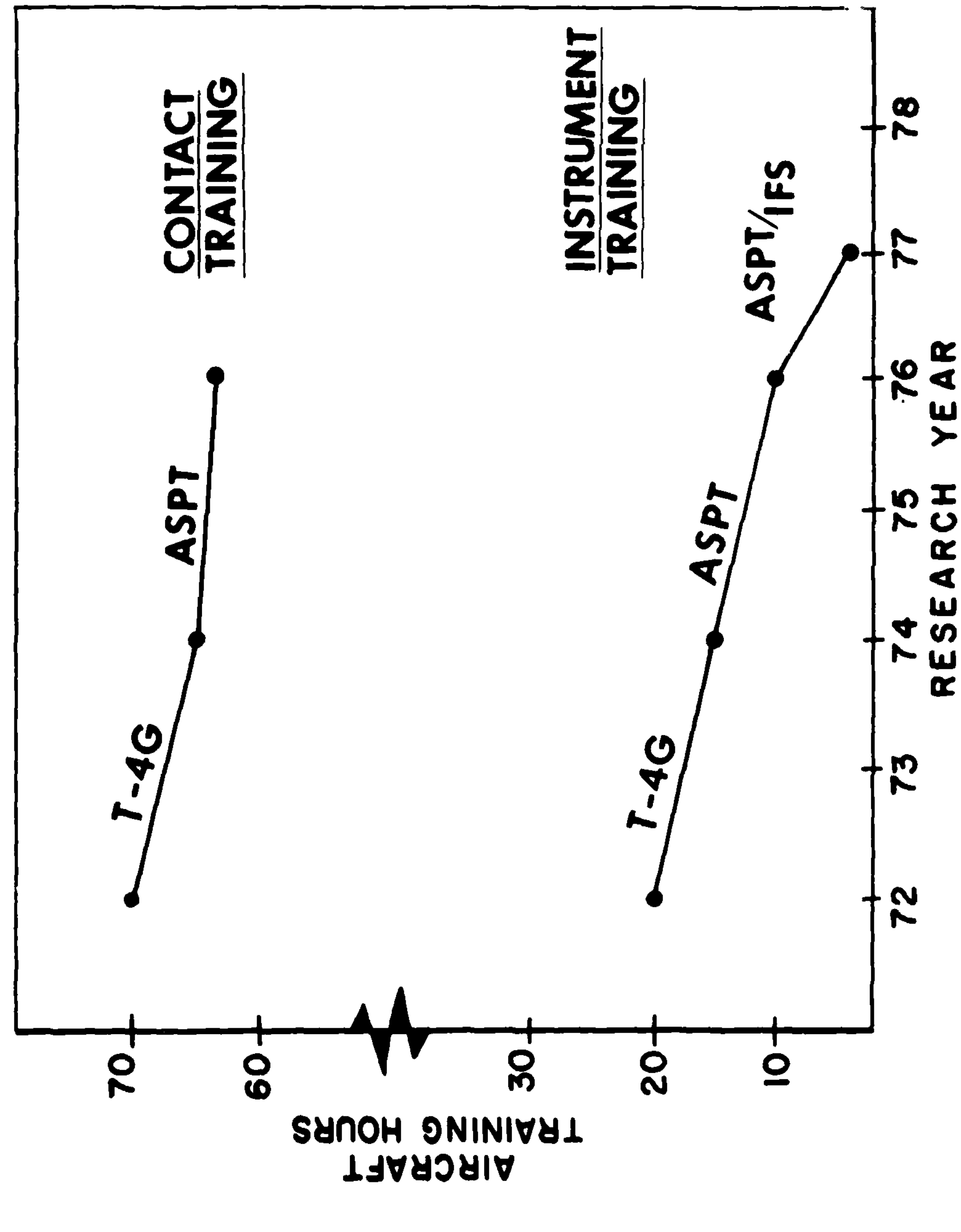
COMPUTER IMAGE GENERATOR (CIG) VISUAL COCKPIT DISPLAY DEPICTING CONTROL TOWER AND HANGARS AT WILLIAMS AFB, AZ



ASPT INSTRUCTOR/OPERATOR CONSOLE. THE TRAINING MISSION CAN BE SET UP, MONITORED, CHANGED, DISPLAYED, AND A HARD COPY PRINTOUT OF FLIGHT DATA OBTAINED FOR COMPARISON WITH A STANDARD CRITERION

The name of the *ASUPT* was later changed by dropping the "U" and it became the *Advanced Simulator for Pilot Training (ASPT)*. This recognized that the simulator could be employed for R&D that has implications not only for undergraduate pilot training, but also for the more advanced conversion, continuation, and mission training.

During the early 1970s, the ASPT was used in R&D that demonstrated how simulation could be employed in undergraduate pilot training to reduce the required number of aircraft training hours in both *contact training* and *instrument training*. The results of these early R&D efforts have been implemented by the Air Training Command in their undergraduate pilot training syllabi.

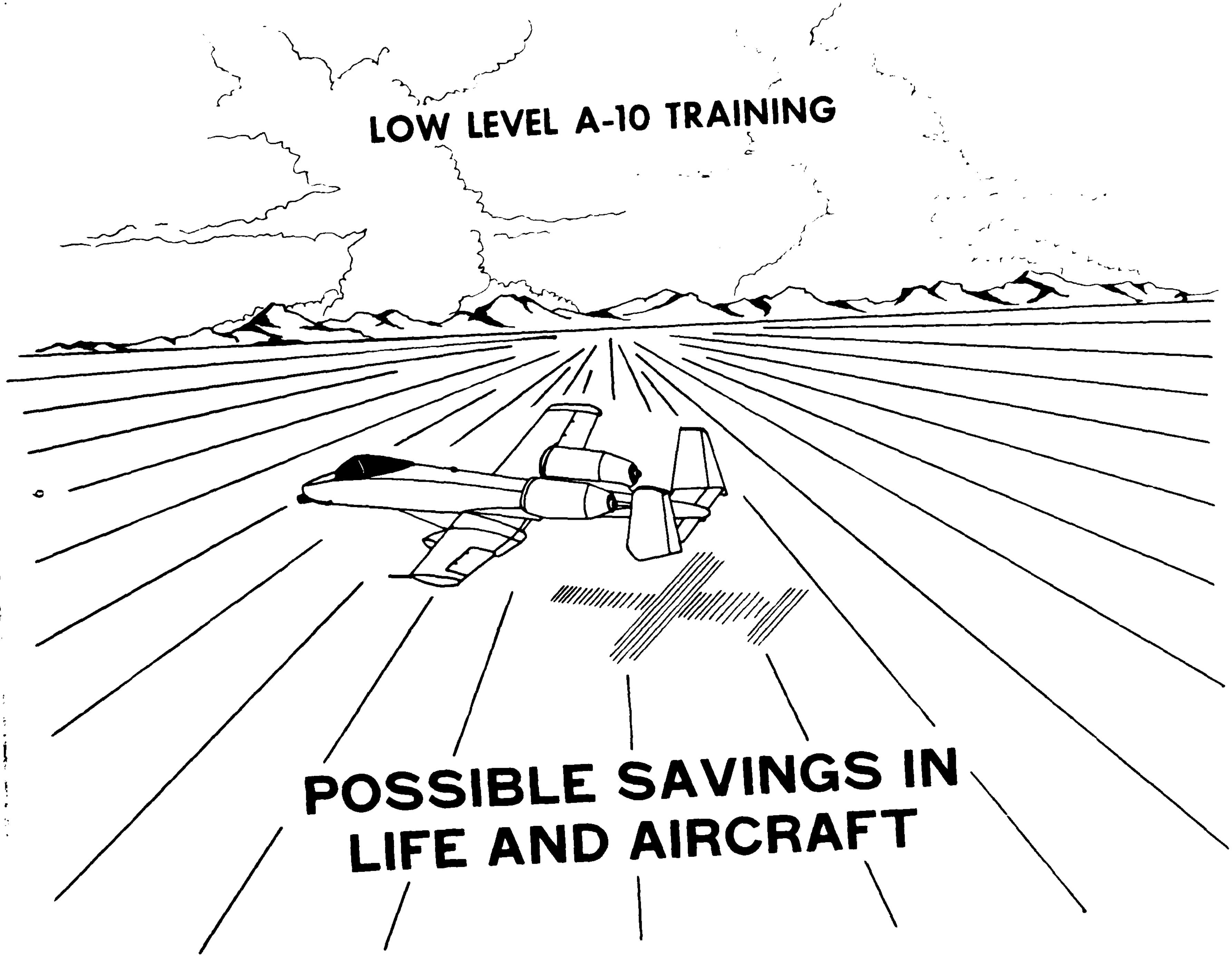


CONTACT TRAINING
INSTRUMENT TRAINING
T-4G
ASPT
T-4G
ASPT
ASPT/IFS
AIRCRAFT TRAINING HOURS
70
60
30
20
10
72
73
74
75
76
77
78
RESEARCH YEAR

Along with the change of name to ASPT came the addition of cockpits and flight-dynamics responses for operational aircraft. With these additions, the ASPT now represents an expression—the Air Force's only expression—of 1981 state of the art for visual flight simulation of A-10 and F-16 (center-thrust fighter/attack) aircraft.

Thus configured, the ASPT can be used for training in air combat tactics and is especially well-suited for low-level flight and air-to-surface weapons-delivery training.

The ASPT requires greater visual system resolution to permit useful training scenarios in air-to-air combat training.

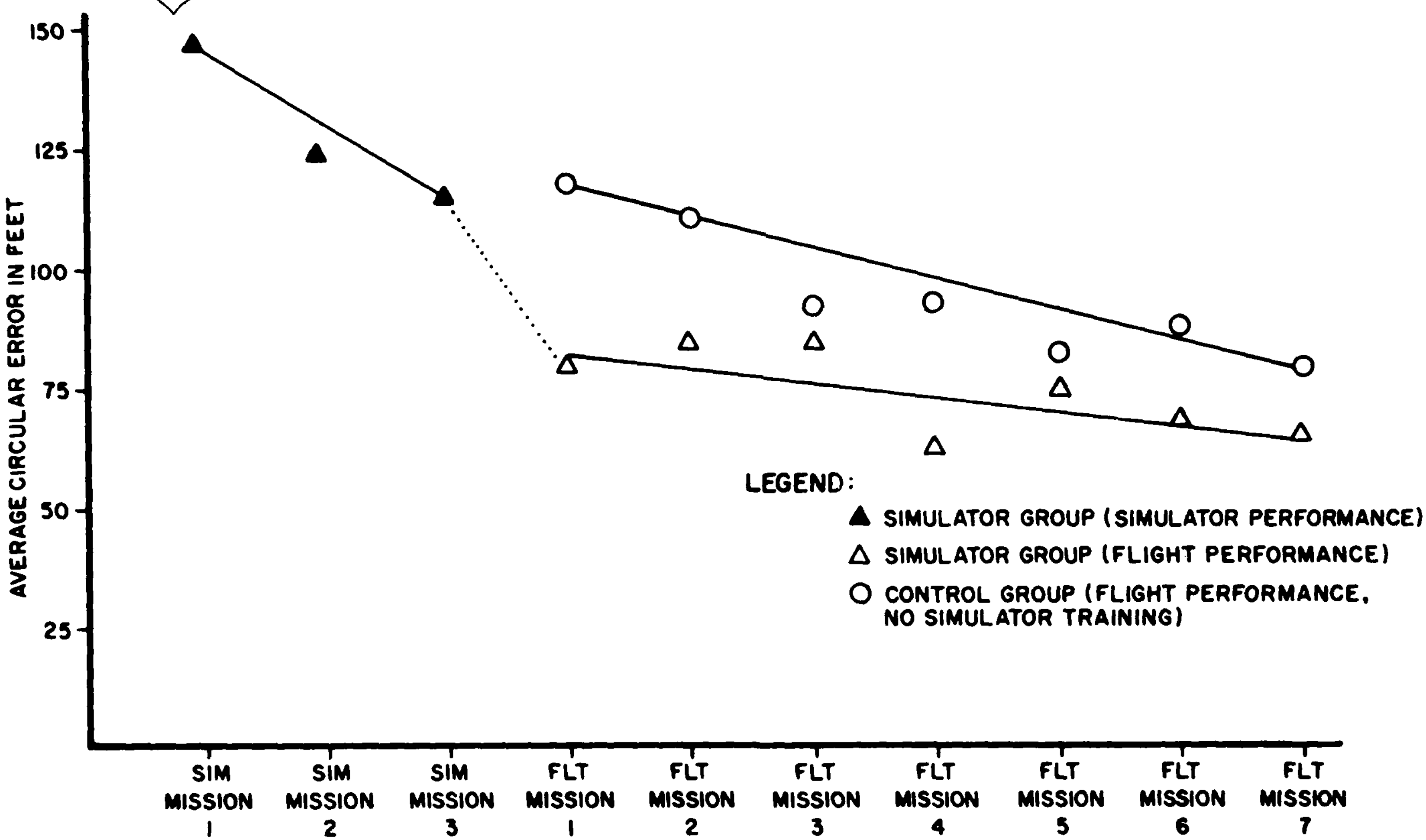

LOW LEVEL A-10 TRAINING
POSSIBLE SAVINGS IN
LIFE AND AIRCRAFT

The ASPT has been employed in classical transfer-of-training (TOT) studies in which the effectiveness of simulator training has been *tested* with *performance* in the aircraft. In these studies, the effectiveness of simulator training has been clearly demonstrated.

For example, with the A-10 employed in the conventional dive bomb task, the training provided with three ASPT-simulated mission-training performances produced an initial reduction of one third in the bombing circular error. The advantage of the simulator-trained pilots continued through all seven of the *actual flight mission performances*, with the bombing circular error being one fifth lower, even on the seventh flight.

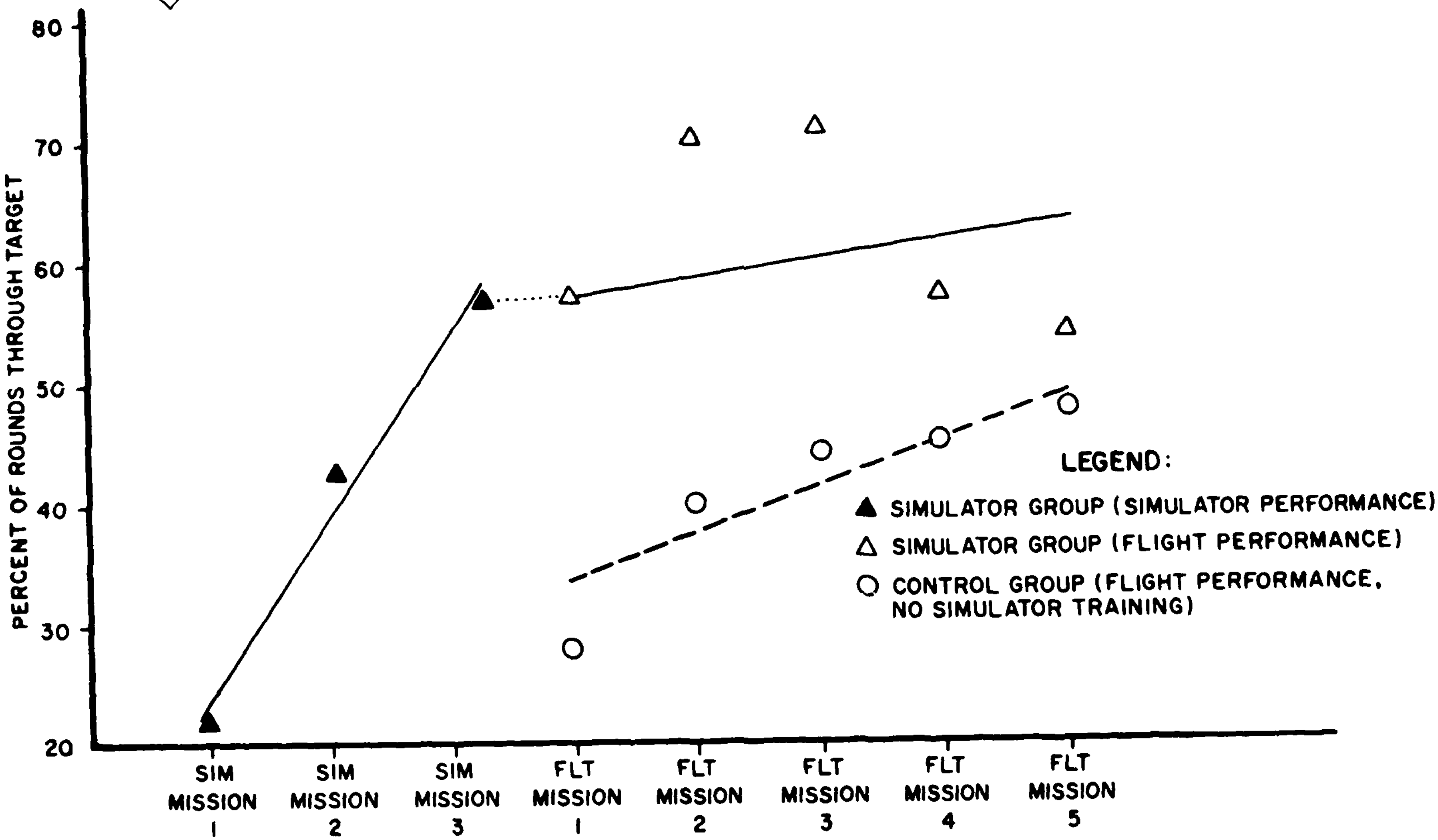
In a very real sense, use of the simulator permitted more-effective training to be accomplished in the aircraft.

TAC CONVENTIONAL DIVE BOMB TASK (A-10)



In training the low-angle strafe task with the A-10, the three ASPT-simulated mission-training performances produced a doubling of the percentage of rounds through the target on the initial flight-training mission relative to pilots who did not have the simulator training, and the advantage continued through all five of the training flights.

TAC LOW ANGLE STRAFE TASK (A-10)

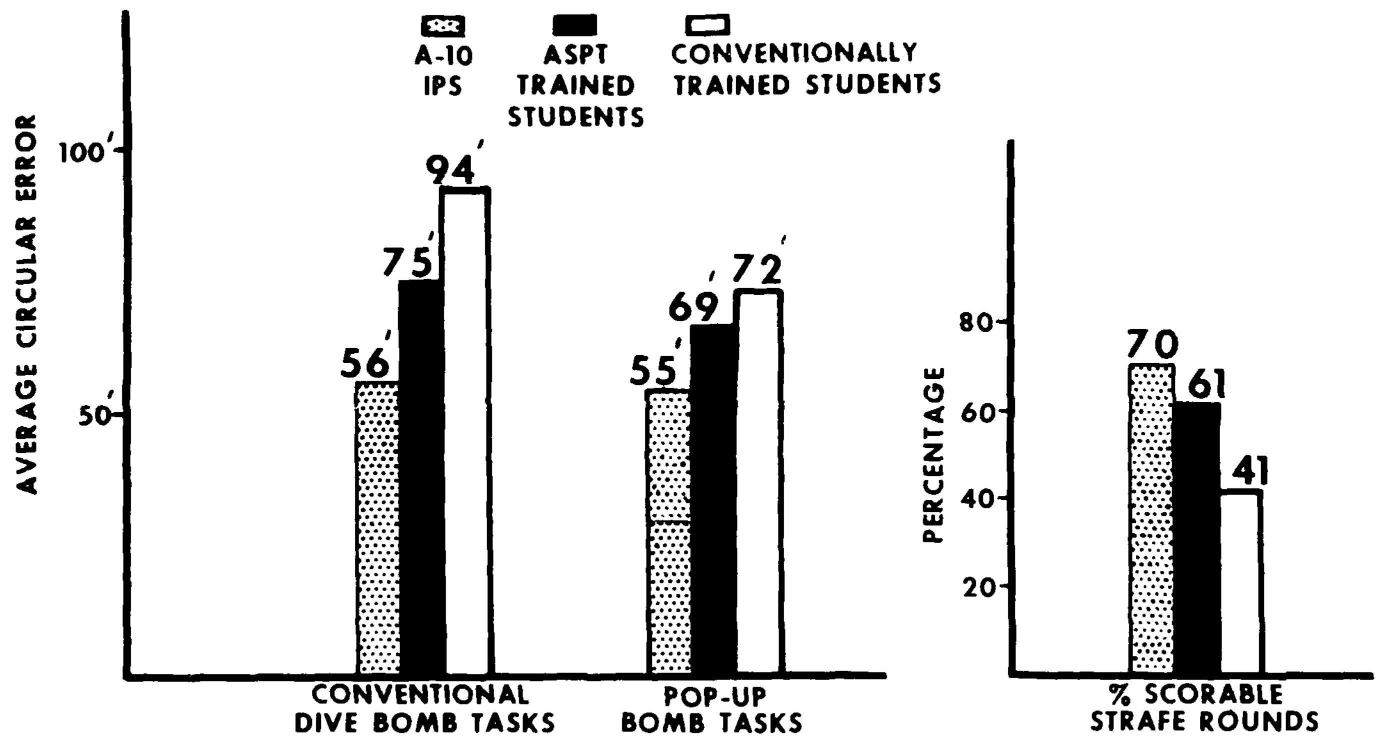


In summary, the transfer of ASPT-simulator training to A-10 performances on the bombing and strafing ranges has been quite positive. On the average, the ASPT-simulator-trained pilots have scored better than conventionally (non-simulator) trained pilots, but not quite as well as the A-10 instructor pilots (IP). *Some* of the ASPT-simulator-trained pilots *did* outscore their IPs, however, and continued to *do so during their training* flights.

Our analyses indicate that three to four sorties are saved per student per event with the three ASPT-simulator training missions and that this amounts to a dollar savings of $2.7M through 1980 A-10 training.

A-10 TRANSFER OF TRAINING STUDIES

R & D FINDINGS WITH ASPT



SORTIES SAVED: 3 - 4 PER STUDENT PER EVENT

DOLLARS SAVED: 2.7 MILLION THROUGH 1980 A-10 TRAINING

Our R&D with the ASPT has been advancing to the area of combat mission training—or training in air combat tactics as we *often call* it. In this work we have employed computer-generated edge-based imagery constrained by a limitation of about 2500 edges. As a result, the visual scene produced is relatively simple—nearly cartoonish in its simplicity.

In a very real sense, the ASPT is a state-of-the-art combat mission trainer. (CMT) not an ideal CMT.

By analogy, and with thanks to the most recent issue of the *American Scientist*, "It may not be a perfect wheel, but it's a state-of-the-art wheel."

We might well ask what would be a "perfect wheel"—an "ideal CMT"?

It would be inexpensive—every pilot would have one.

It would be portable—perhaps it would fit on a helmet and store in a briefcase.

It would have rich, realistic environmental visual features—perhaps "fixed," but updated to "now" in terms of targets, environmental changes, damage, seasons, *etc.*

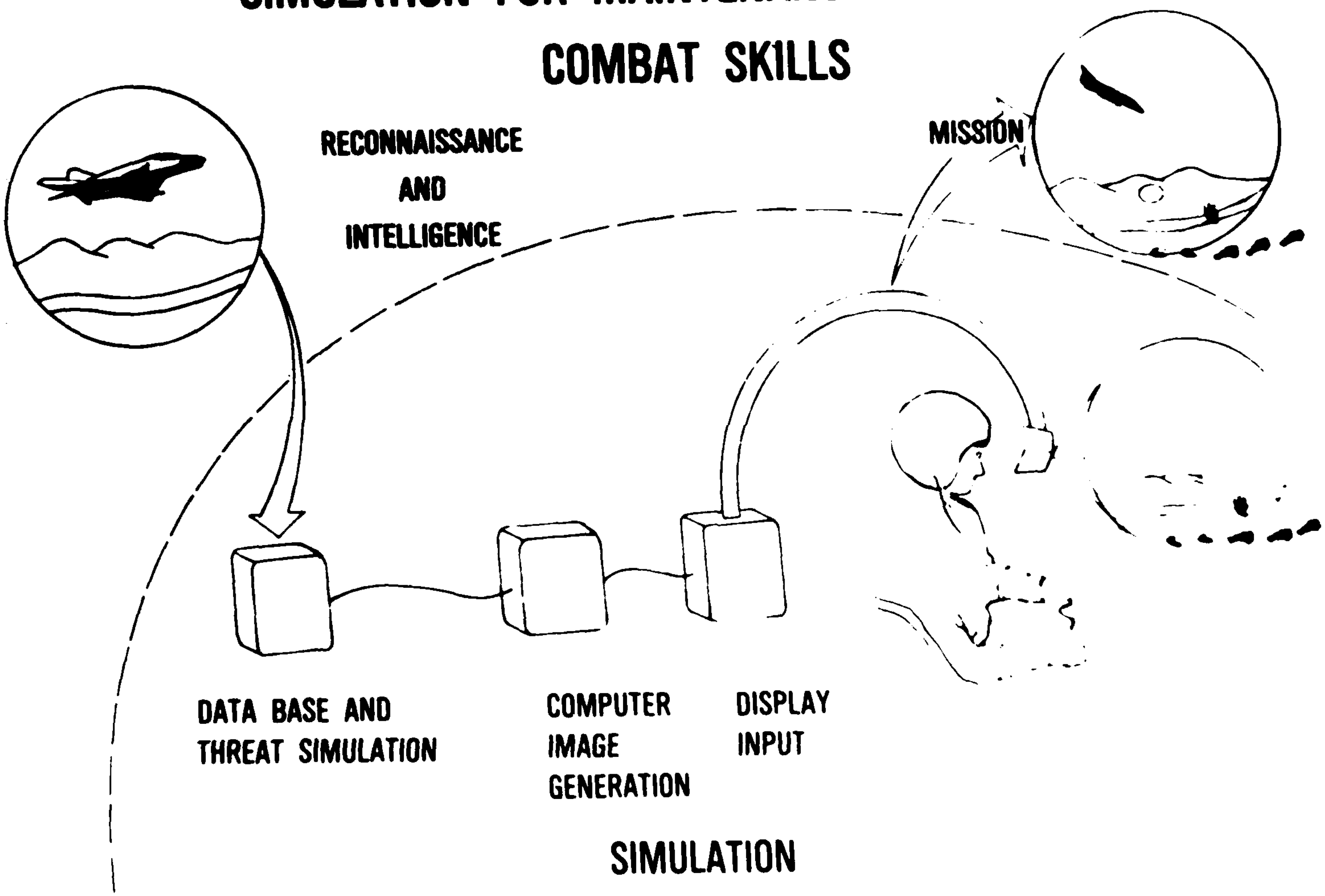
It would permit each combat pilot "to fly" his mission in the CMT-simulated environment several times before he even boarded his aircraft to fly the real mission.

The reader is referred to the copyrighted cartoon which appears on the lower half of page 275 in the May-June 1981 issue of the *American Scientist.* (*American Scientist*, 1981, 69 (3), 275.)

Conceptually, an ideal CMT would take reconnaissance and intelligence information from the real world into its data base.

The information in the data base, mixed with threat simulation, would then be transformed through *computer image generation* into a display input that could be presented to the pilot with, say, a helmet-mounted display rather than the large CRT-mosaic display system currently employed in the ASPT. The "cockpit" might even be as simple as a chair and a "broom-stick" control, but the experience provided for the pilots in the CMT simulation would be quite realistic relative to the actual mission that they would then fly in the real world.

SIMULATION FOR MAINTENANCE OF CRITICAL COMBAT SKILLS



What we have described as an *ideal CMT* may be approached through a *state-of-the-art CMT.*

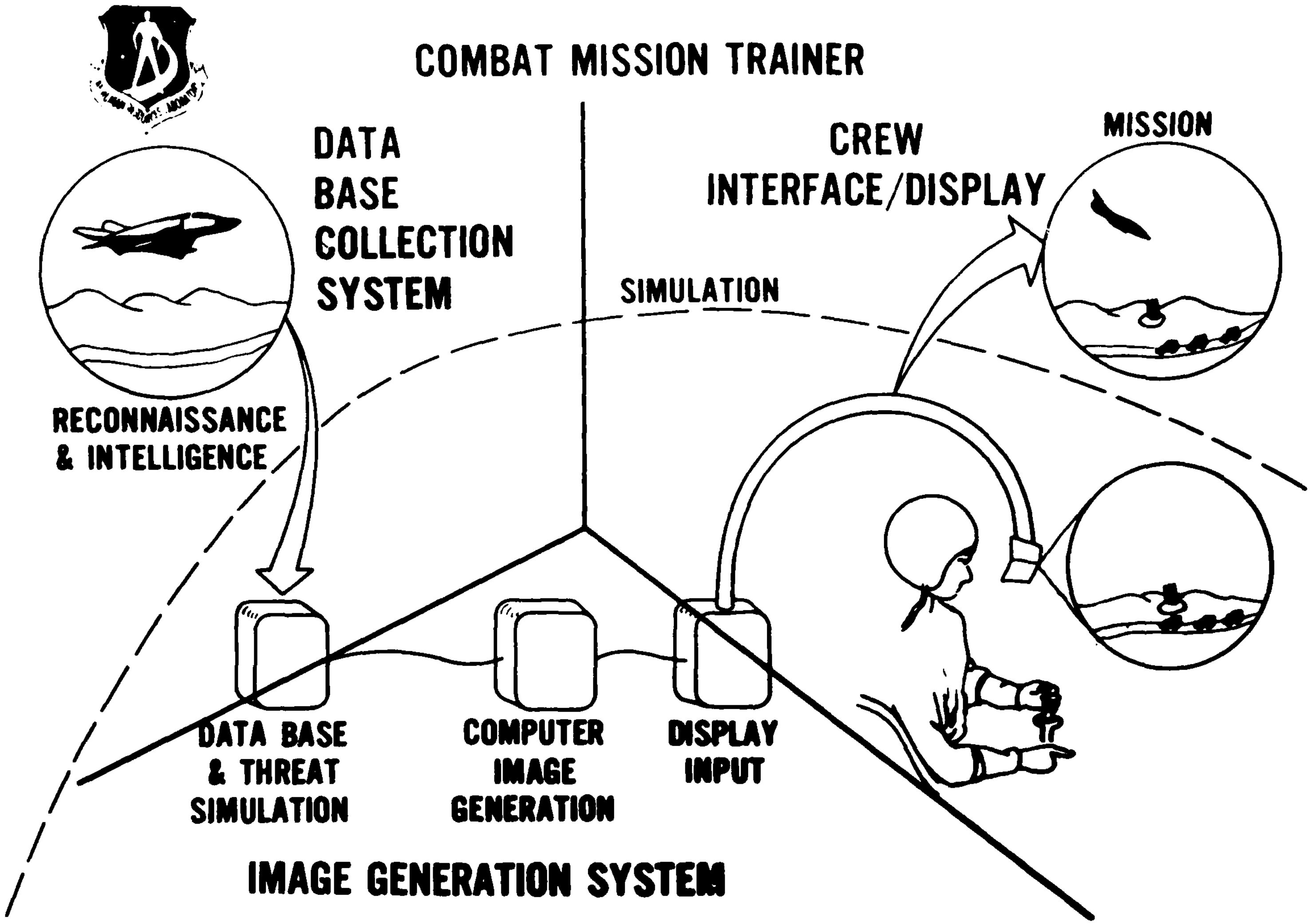
We look upon the development of a state-of-the-art CMT as involving essentially three primary systems:

A *data base collection system* that includes the collection of the reconnaissance and intelligence information and its integration into the CMT data base.

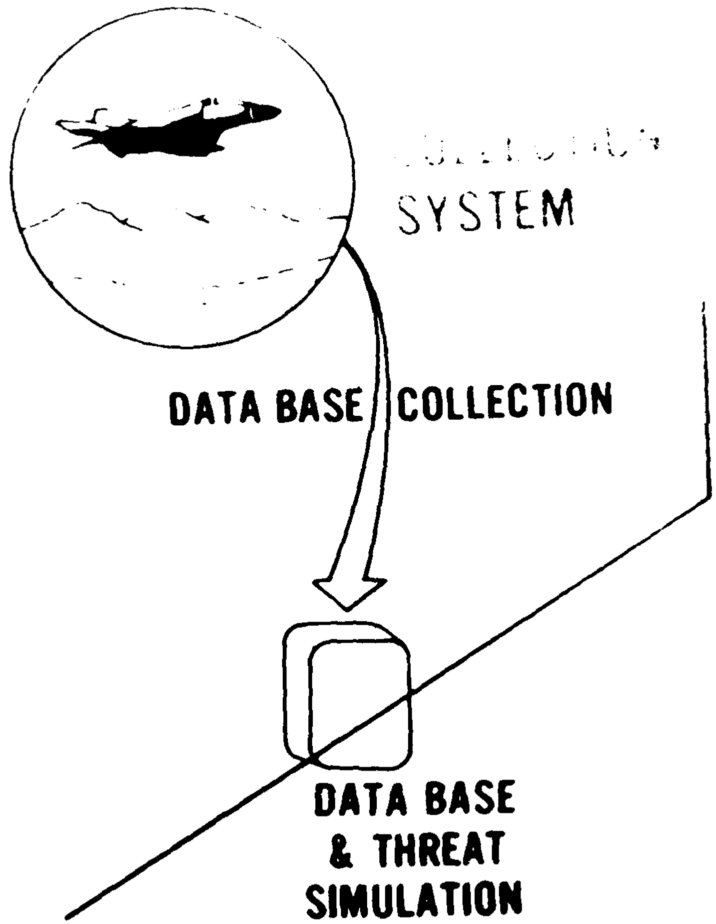
An *image generation system* that can operate on the kind of information in the data base to produce the kind of input required by the display.

A *crew interface/display system* that can take the display-input signals and produce a suitable visual display for the aircrew, interacting with the control and flight-dynamics responses of the CMT's aircraft *flight simulation.*

Let us review briefly the status of AFHRL R&D in each of these three areas.


COMBAT MISSION TRAINER
DATA BASE COLLECTION SYSTEM
RECONNAISSANCE & INTELLIGENCE
SIMULATION
CREW INTERFACE/DISPLAY
MISSION
DATA BASE & THREAT SIMULATION
COMPUTER IMAGE GENERATION
DISPLAY INPUT
IMAGE GENERATION SYSTEM

In the *data base collection system*, AFHRL is following the Defense Advanced Research Projects Agency (DARPA) program for the most part, but we do have one task study underway with a contractor to develop the technology to produce a low-level flight image data base via photographic and video disk technologies. Our AFHRL in-house work includes some non-real-time video disk development. In addition, our engineering program refinements include the development of threat-simulation capabilities.



STATUS

- DARPA PROGRAM
  - MULTIPLE FLYOVER
  - DMA/DIGITAL DATABASE
  - OBLIQUE OVERHEAD IMAGES
  - PERCEPTRONICS, INTERACTIVE TV, ESL, LIPPMAN/MIT
- AFHRL/VOUGHT PHOTOGRAPHIC/VIDEO DISK
  - LOW LEVEL IMAGE DATA BASE TASK STUDY
- AFHRL IN-HOUSE NON-REAL-TIME/VIDEO DISK (AEOSS)
  - PROGRAM REFINEMENT (ENGINEERING/RESEARCH)

In the area of the *image generation system*, AFHRL is pursuing both edge-based and non-edge-based computer-generated imagery (CGI), as well as video disk image processing technology.

STATUS

- NON-EDGE CGI
  - PHASE I PROGRESS EXCELLENT
- VIDEO DISK IMAGE PROCESSING
  - VOUGHT STUDY CONTRACT TO BE LET
- EDGE BASED CGI
  - PROJECT 2363 CIG STARTED 1 JUL 80

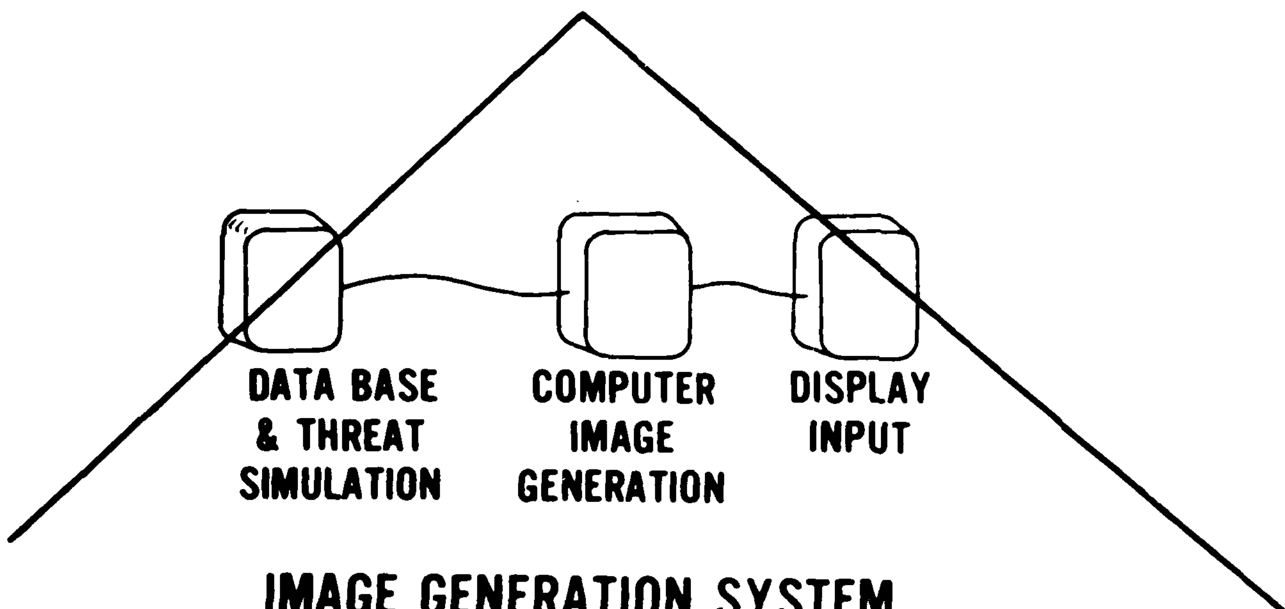


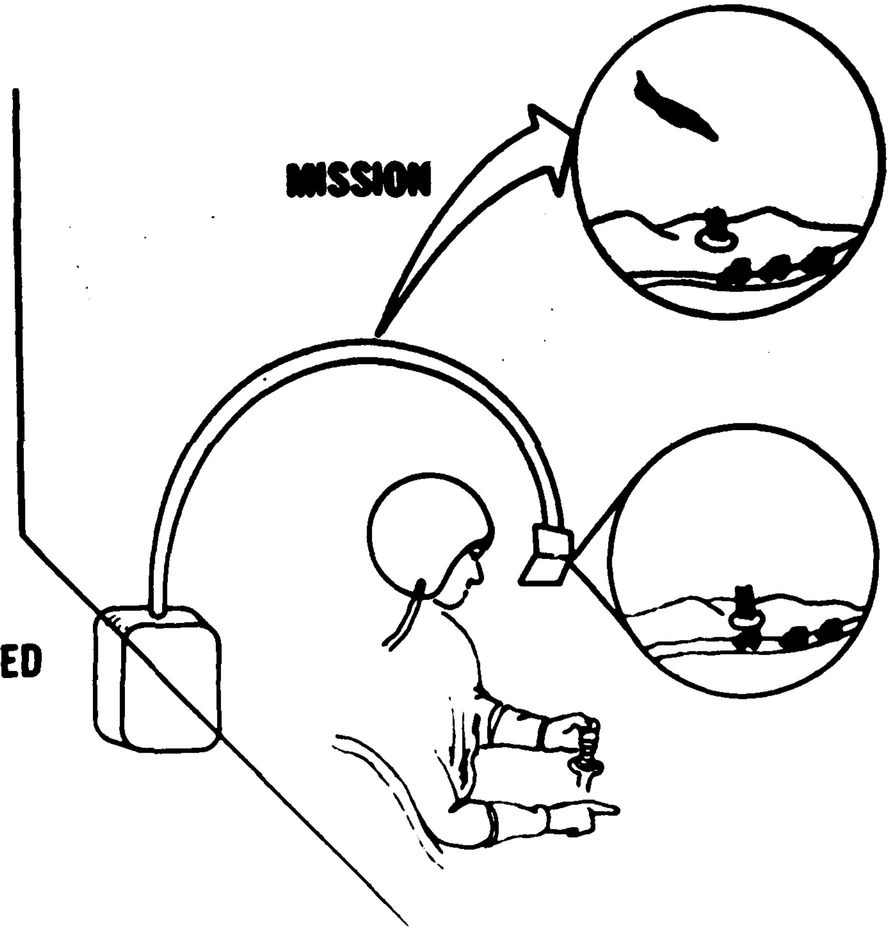
IMAGE GENERATION SYSTEM

In the area of the *crew interface/display system*, a relatively major effort is being developed with AFAMRL to pursue the technology for helmet mounted displays—primarily through further development of the Visually Coupled Airborne Systems Simulator (VCASS) by AFAMRL and the independent development of a fiber-optics helmet mounted display (FO/HMD). We are also developing modular-micro computer linkages for generic cockpits and instructor/operator stations. Finally, in cooperation with the U.S. Army, AFHRL is developing further the mosaic-CRT display technology that has been so successful in the ASPT.

CREW INTERFACE/DISPLAY

STATUS

- HELMET MOUNTED DISPLAYS (AFAMRL)
  - ENGINEERING APPROACH FOR FIBER OPTICS IN DEVELOPMENT
  - VCASS DEMONSTRATION IN MAR 81
- MODULAR-MICRO LINKAGES (AFHRL)
  - ENGINEERING PLAN COMPLETED
- MOSAIC CRT (AFHRL)
  - DUAL PROJECTOR HIGH RESOLUTION INSET (2363/ARMY)

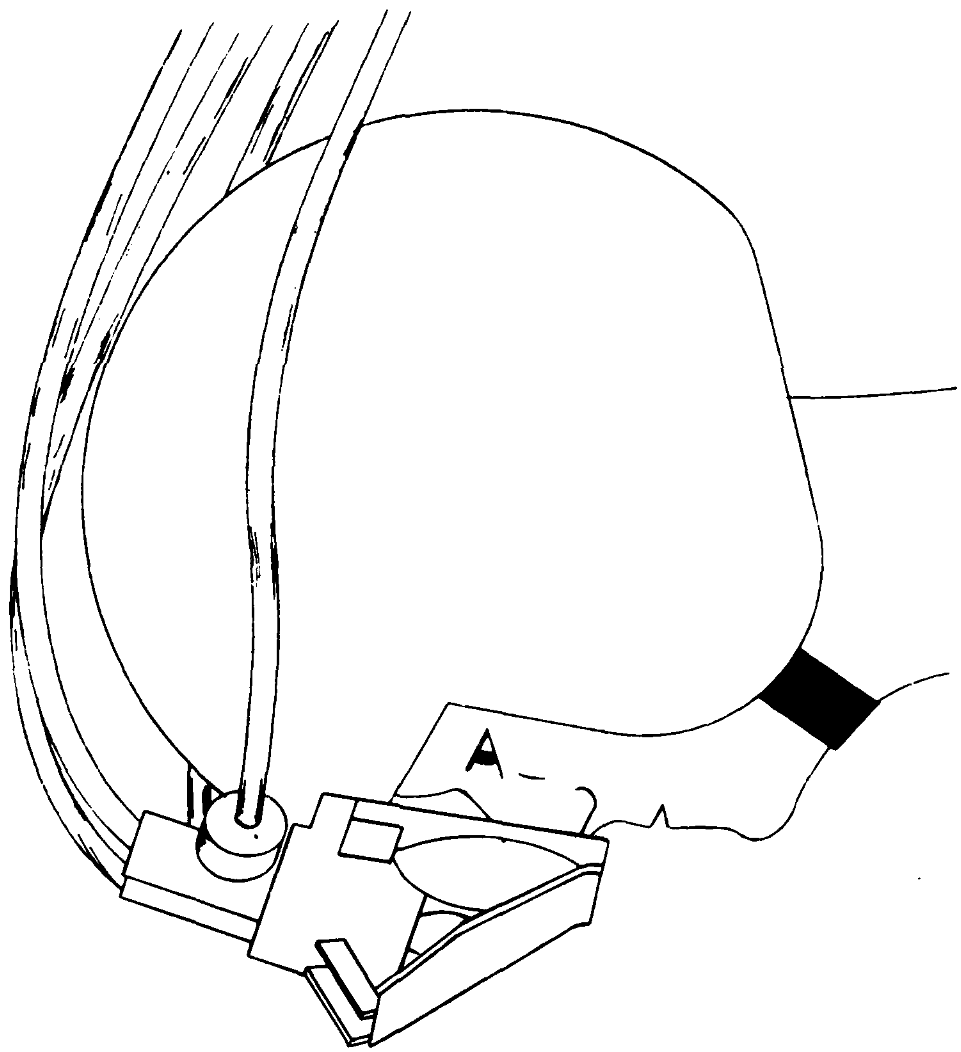


The FO/HMD shows promise as a potential display system that could move us far along the road from a state-of-the-art ASPT towards an ideal CMT. With such a system as a replacement for the large and expensive mosaic-CRT visual display system, we might be able to develop a state-of-the-art CMT that, if not fully *portable* as would be an ideal CMT, would at least be much more *transportable* than the ASPT and similar devices. AFHRL views the VCASS/HMD development as a lower-risk, but intrinsically less-capable back-up for the FO/HMD.

However, in order to provide a technology demonstration of a state-of-the-art CMT, or even of the helmet mounted display part of it, AFHRL will need a great many efforts, a great deal of support, and a substantial supplement to its resources.

AFHRL and the Director of Laboratories at Air Force Systems Command are presenting the case for a technology demonstration of a CMT to Air Force management—the Air Staff and Major Commands (MAJCOMS)—who, if they are to allocate resources to this effort, will have to deny those resources from other efforts or from other acquisitions. How could one decide that the demonstration of an FO/HMD is more valuable, more important to have, than (a) more bullets, missiles, or aircraft, (b) more spares, (c) more or better training, (d) more personnel, military or civilian, (e) more of other R&D, or (f) increased pay and allowances and the greater retention implied?

The prudent manager would demand comparisons of the *impacts* (real or potential) of the various options before reaching a decision. He would want to know, "What difference would it make" if he decided one way in favor of another.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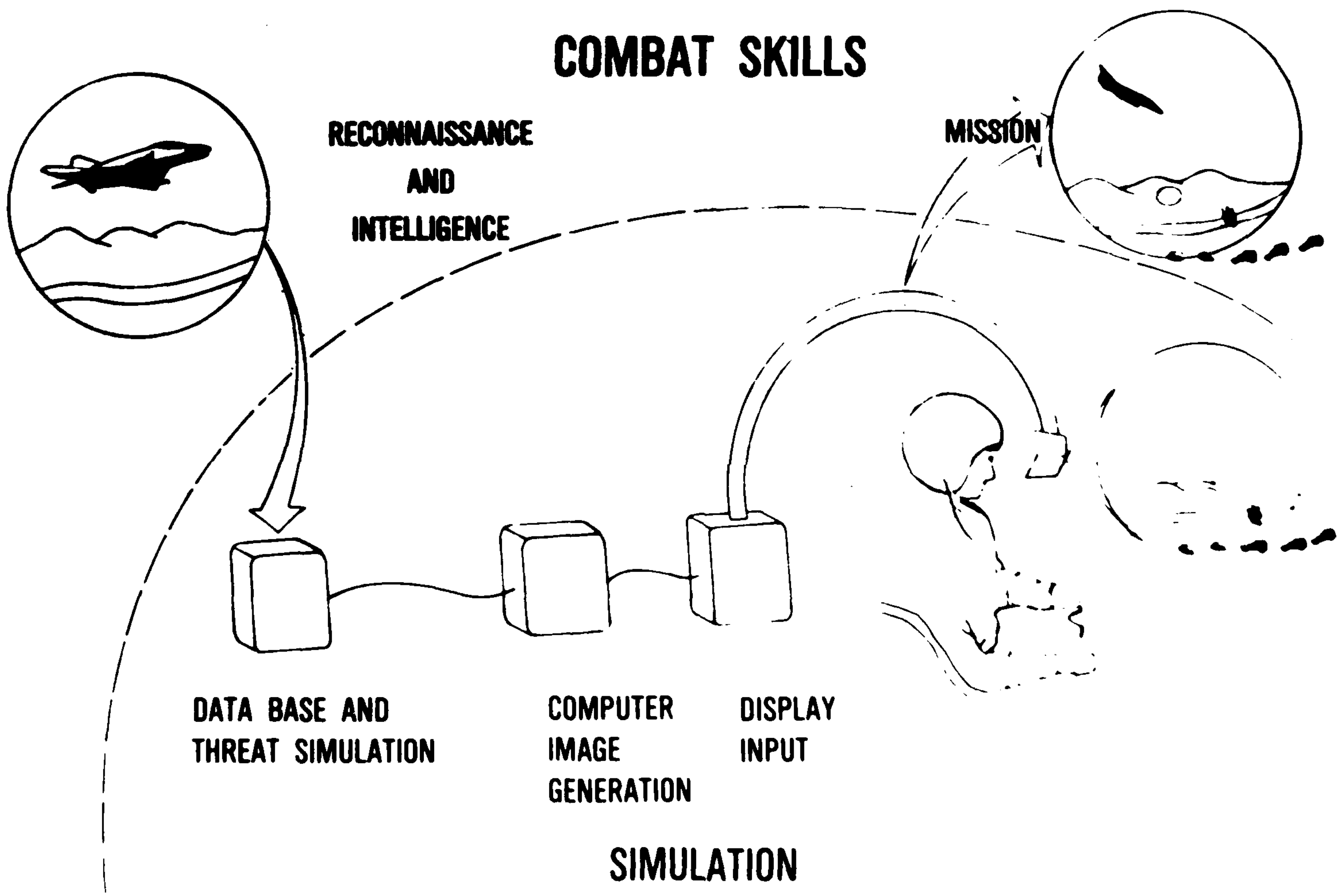
IV. THE IMPACTS

Increasingly, questions of potential impacts, risks, and alternatives *are being asked* (with the teeth of budget-request approval or disapproval) at every level within the Defense-budget R&D chain—from the Armed Services and Appropriation Committees of the House of Representatives and Senate of the U.S. Congress, through the Department of Defense and the Air Staff, to the Air Force Systems Command, Director of Laboratories, and the AFHRL Commander.

The technology-base R&D community generally, and our part of it especially, is not well-practiced or *experienced in answering* such questions with credible quantitative responses. We need to learn how to do so. We can no longer expect our programs to be continually supported on the promise of vaguely expressed potential impacts such as "improved training," "enhanced performance," "more efficient personnel utilization," or "more effective use of resources." Instead, we have to provide *credible, quantitative analyses* of the impacts (real or potential) of the products we propose to develop. Unless we can show "What difference it would make" were we *successful in our proposed R&D effort*, the effort might never get started—not even the efforts needed for so intrinsically appealing a product as an ideal CMT, and especially not the underlying R&D efforts on image generation and display for flight simulation to be employed in air combat training, the areas covered so well in this IMAGE-II conference.

SIMULATION FOR MAINTENANCE OF CRITICAL COMBAT SKILLS



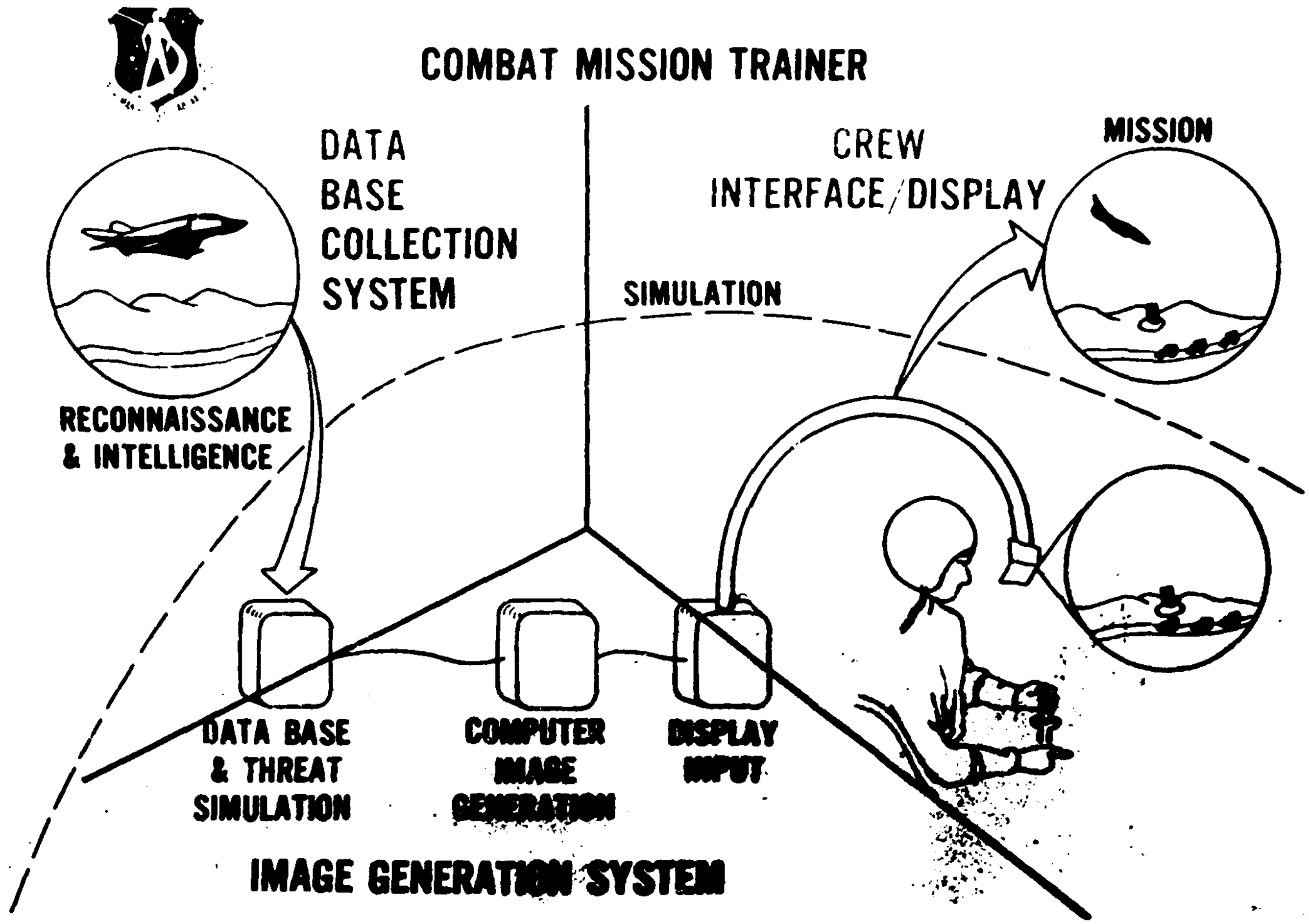
A. THE CONTEXT

Remember, Air Force management is being asked to support the development of a state-of-the-art CMT—the technology demonstration of how far towards an ideal CMT we could get with current technology. "Support" means to put money and resources there, and therefore not to put the money and resources in other places. They need to know the extent to which success in this effort would be better—more beneficial, or potentially so—than success in other, essentially alternative, technology developments. Of course, they need also to know the risks, or probabilities of failure and success, and the costs of the proposed R&D efforts competing for funds from a not-unlimited R&D budget.

To what extent would the successful development of a state-of-the-art CMT be (potentially) more beneficial than some additional improvements to, for example, (a) high-energy laser, (b) radar, (c) FLIR, or even (d) stealth-aircraft technology? To what extent would it be more beneficial than the acquisition of even just a few more weapons, munitions, or spares?

The question for Air Force management is not trivial. For example, if the 5-year development cost of a state-of-the-art CMT were equal to the cost of just one additional F-15 aircraft, how could management ever decide in favor of the CMT development? The F-15 could be expected to damage, perhaps even destroy, some enemy elements. Would the proposed CMT be able to damage or destroy any enemy element? If the proposed CMT has any potential to contribute to "force," if it constitutes any sort of threat to an enemy, we must, and should be able to, articulate that potential—in credible and quantitative terms.

Let's look at the logic one might employ in such an articulation.

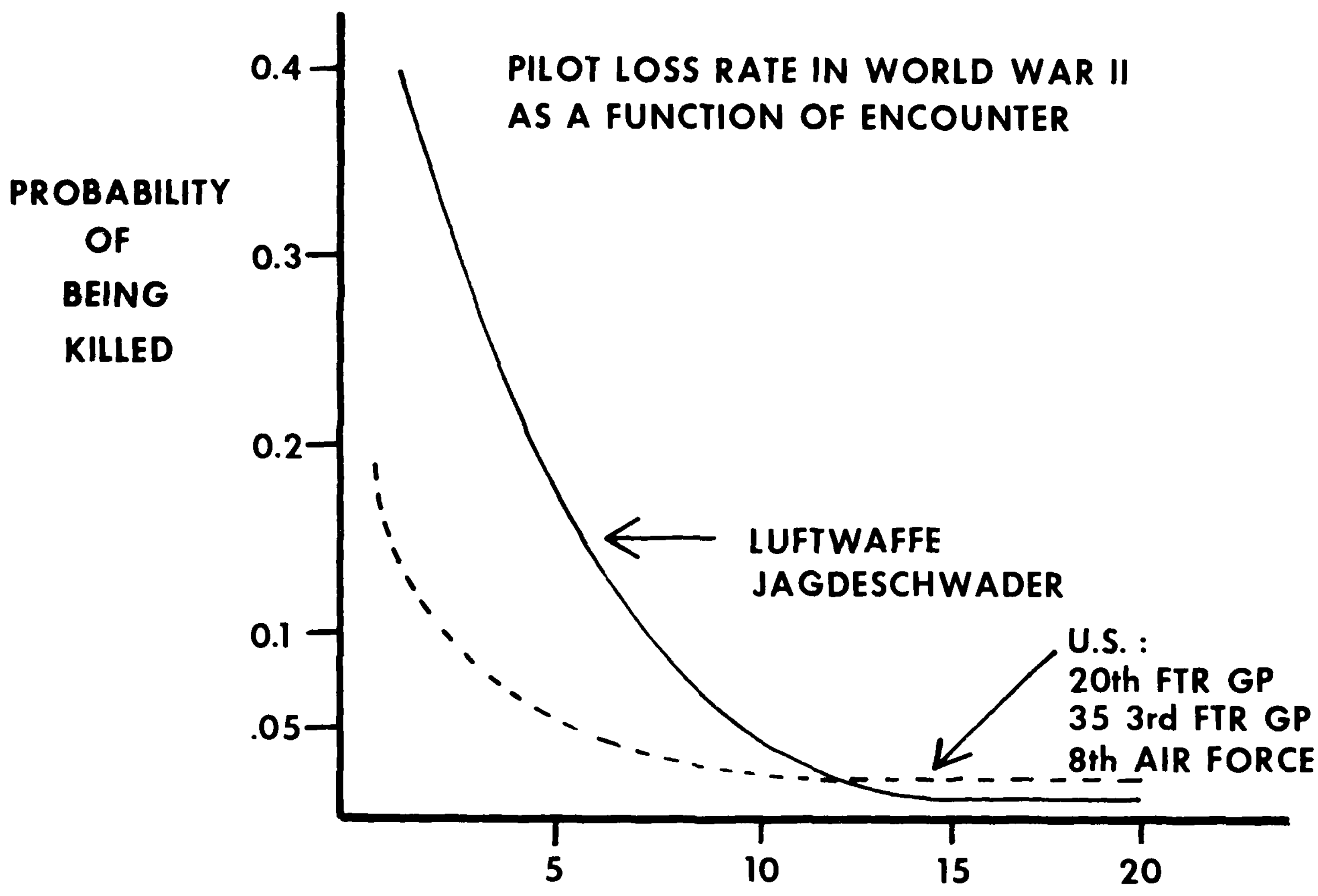

COMBAT MISSION TRAINER
DATA
BASE
COLLECTION
SYSTEM
CREW
INTERFACE/DISPLAY
MISSION
SIMULATION
RECONNAISSANCE
& INTELLIGENCE
DATA BASE
& THREAT
SIMULATION
COMPUTER
IMAGE
GENERATION
DISPLAY
INPUT
IMAGE GENERATION SYSTEM

B. THE LOGIC: A NOTIONAL CMT IMPACT ANALYSIS

Let's begin with *data* regarding what has happened in the past and what we might expect to happen were we to enter armed conflict now. We have our own and Luftwaffe data from World War II. We also have our own later experiences, as well as those of our allies such as the Israeli 6-day war.

All the data show that the major losses in air combat occur during the aircrews' first 8 to 10 missions. This occurs even though we know it and therefore send the new aircrews on the easiest and least dangerous missions at the beginning of their combat tours.

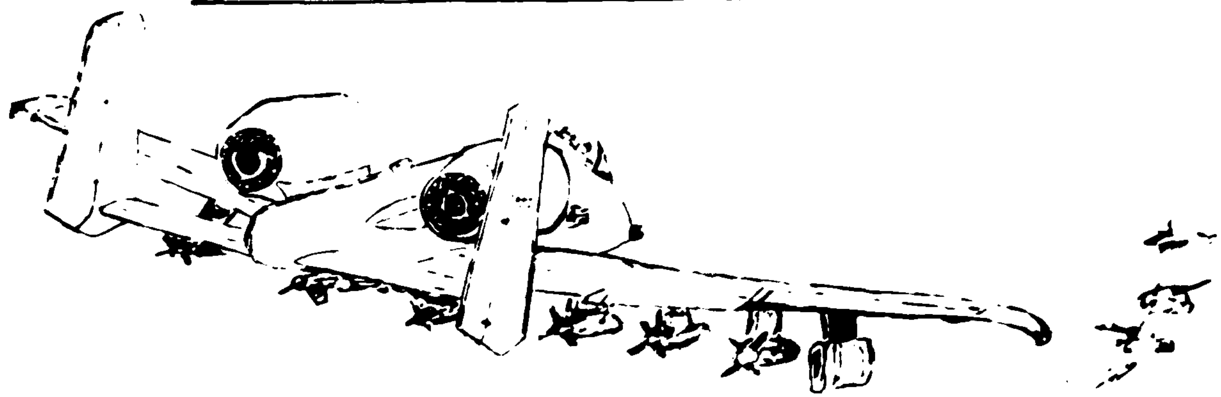
It seems safe to infer that the surviving aircrews have learned something during those first 8 to 10 missions. Suppose we could train all aircrews in that "something," whatever it is, before they went into combat. What difference would it make?

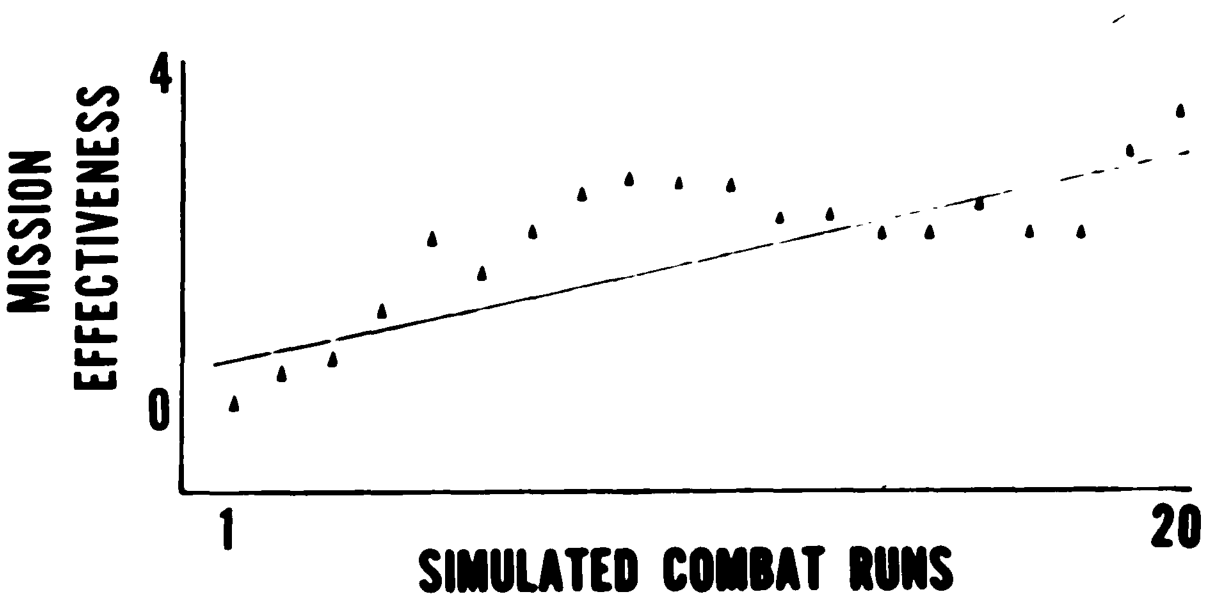

PILOT LOSS RATE IN WORLD WAR II
AS A FUNCTION OF ENCOUNTER
PROBABILITY
OF
BEING
KILLED
0.4
0.3
0.2
0.1
.05
LUFTWAFFE
JAGDESCHWADER
U.S. :
20th FTR GP
35 3rd FTR GP
8th AIR FORCE
5
10
15
20

On the first day of this conference, in the first session, Bob Kellogg presented the data of a feasibility study that we refer to as the "Combat Environment Study." The data showed a *learning curve* for experienced A-10 pilots "flying" the A-10 configured ASPT twenty times through an area defended by "enemy SAMs and AAA batteries" to "attack" an "enemy tank."

That is to say, *experienced* A-10 pilots produced a learning curve over the course of 20 simulated air-to-surface combat missions.

A-10
COMBAT ENVIRONMENT



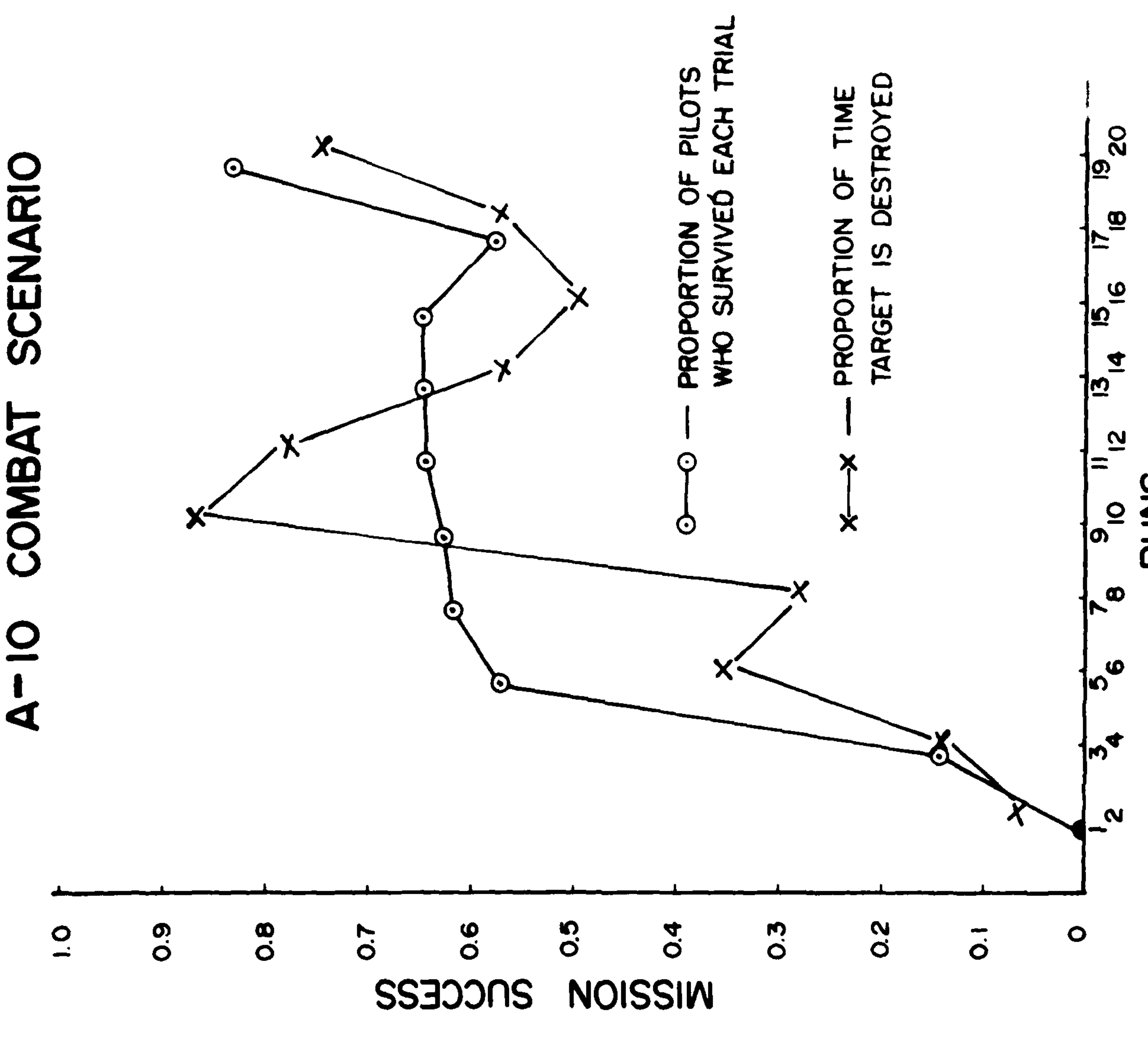


The learning curve was a composite of two parts: the pilots first learned the "defensive" elements of *the mission* (how to survive the threats), then they learned how to complete successfully the "offensive" elements of the mission (how to destroy the enemy target), then finally they learned how to do both together (how to integrate the "defensive" and "offensive" elements into a single task).

Incidently, this integration is apparently more of a *cognitive skill* than it is a psychomotor or procedural skill.

This study was, indeed, a "feasibility" study. We wanted to see the extent to which a simulator like the ASPT could be employed to train air combat tactical skills, even where we were not fully able to define the specific skills *involved*. The data look quite valid even with all their faults—and there are many: for *example*, (a) only seven subjects with an additional five replicating to half the trials, (*b*) *only* 20 trials (10 in the replication), (c) all trials limited to a single scenario except for the specific location of the tank/target along a road, (d) only one threat could fire at a time, and (e) no transfer trial to either the aircraft or even to just a different scenario in the simulator. With the appropriate adjustments to scales and metrics, our data map directly onto the Luftwaffe World War II data and are confirmed by our own later experiences as well as the data of our allies.

These behavioral data form a crucial foundation to the development of this notional CMT impact analysis—the kind of analytical statement needed to win support for the proposed engineering and behavioral CMT development.



A-10 COMBAT SCENARIO
MISSION SUCCESS
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
RUNS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
PROPORTION OF PILOTS WHO SURVIVED EACH TRIAL
PROPORTION OF TIME TARGET IS DESTROYED

Before we use these behavioral data to assess the potential impact of CMT or ASPT-like simulator training in air combat tactics, let us establish a baseline.

Let's assume that the historical (Luftwaffe, U.S.A., Israeli) data predict what we would experience if world armed conflict were to begin today, say in the European Theater. There are combat models that can be employed, and with them and the historical data applied to both sides, along with other characteristics and parameters such as different numbers of aircraft, different "lethalities," different threats, etc., we could predict residual force status on Day 1, Day 2, Day 3, Day 4, etc.

The results could be presented in a simple table. The columns are the ordinal days of conflict. There are two rows: one for the "Blue" forces and one for the "Red." The entries in the table would be the number of aircraft remaining in each force at the end of each day.

This table constitutes the *baseline*—the expectation of what would happen with no change in the status of the forces from today to the day conflict begins.

AIRCRAFT REMAINING

FORCE	END OF CONFLICT-DAY			
	1	2	3	4 . . . n
RED	i_1	i_2	i_3	$i_4 \ldots i_n$
BLUE	j_1	j_2	j_3	$j_4 \ldots j_n$

Now let's assume that through training, with use of air combat tactics and training simulators like the ASPT or the proposed CMT, we could change the level of experience of the "Blue" force aircrews—just like we have shown to be feasible in the Combat Environment Study.

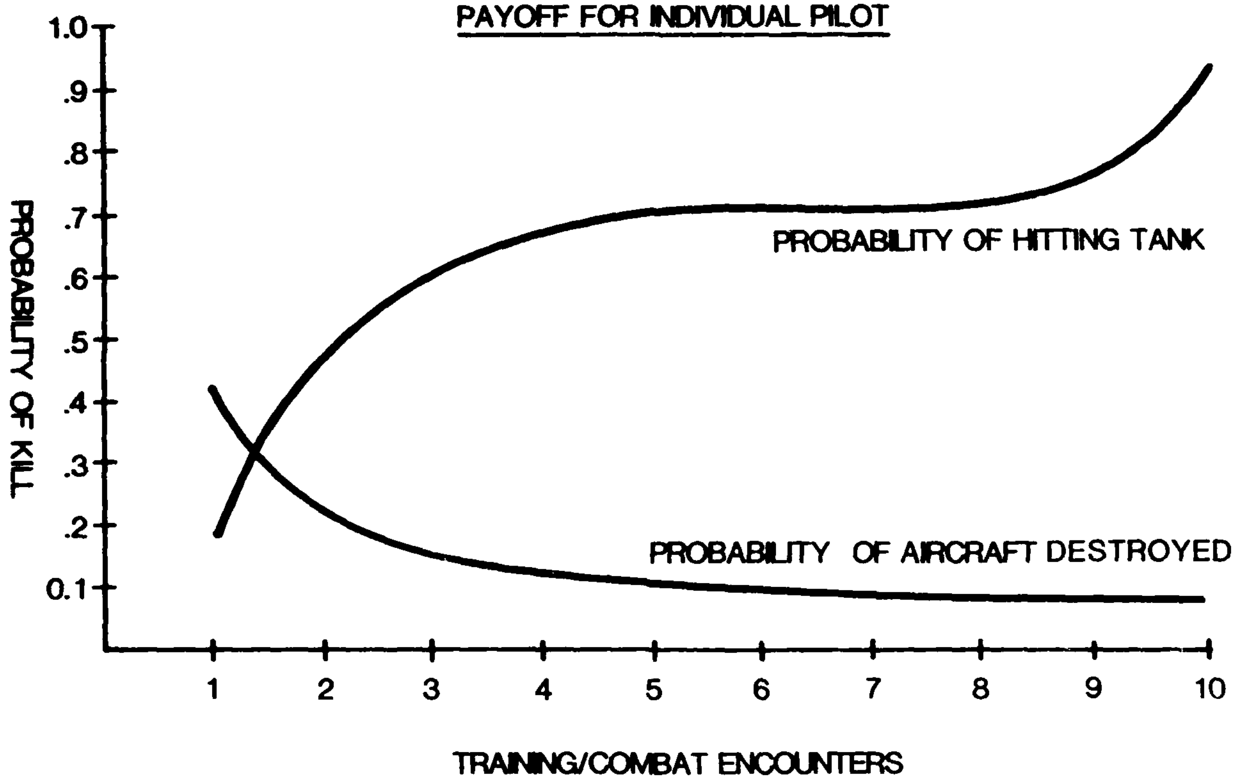
Then let's rerun the same European combat model with these new "experience" parameters. We could do so as a function of the number of training trials or the number of actual combat missions, perhaps even equating the learning of two training trials as equivalent to one combat mission and calling them "encounters."

The payoff for the individual pilot might be as shown for the close air support and battlefield interdiction missions.

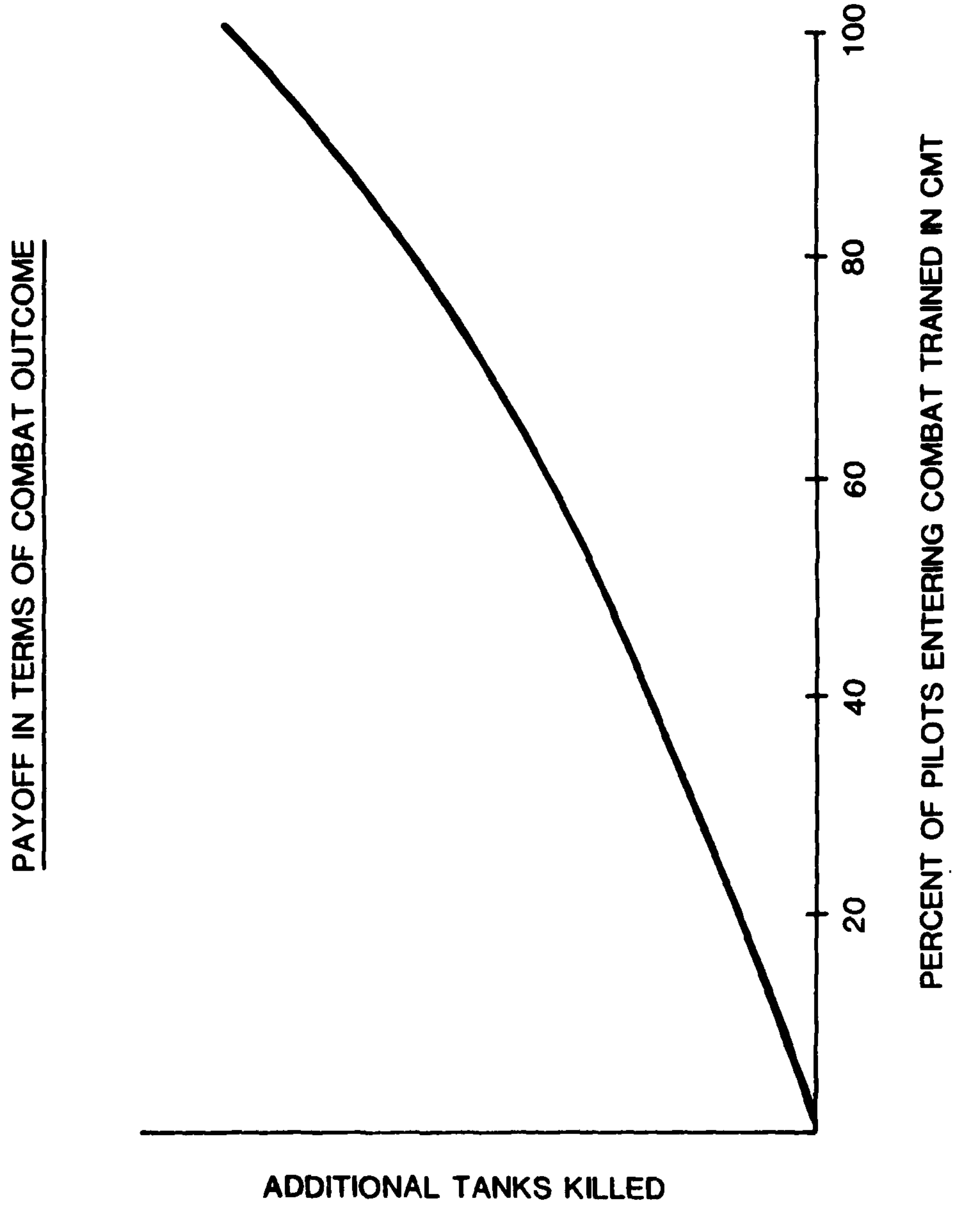
BENEFITS OF COMBAT MISSION TRAINERS (CMT)

CLOSE AIR SUPPORT (CAS) & BATTLEFIELD INTERDICTION (BI)

PAYOFF FOR INDIVIDUAL PILOT



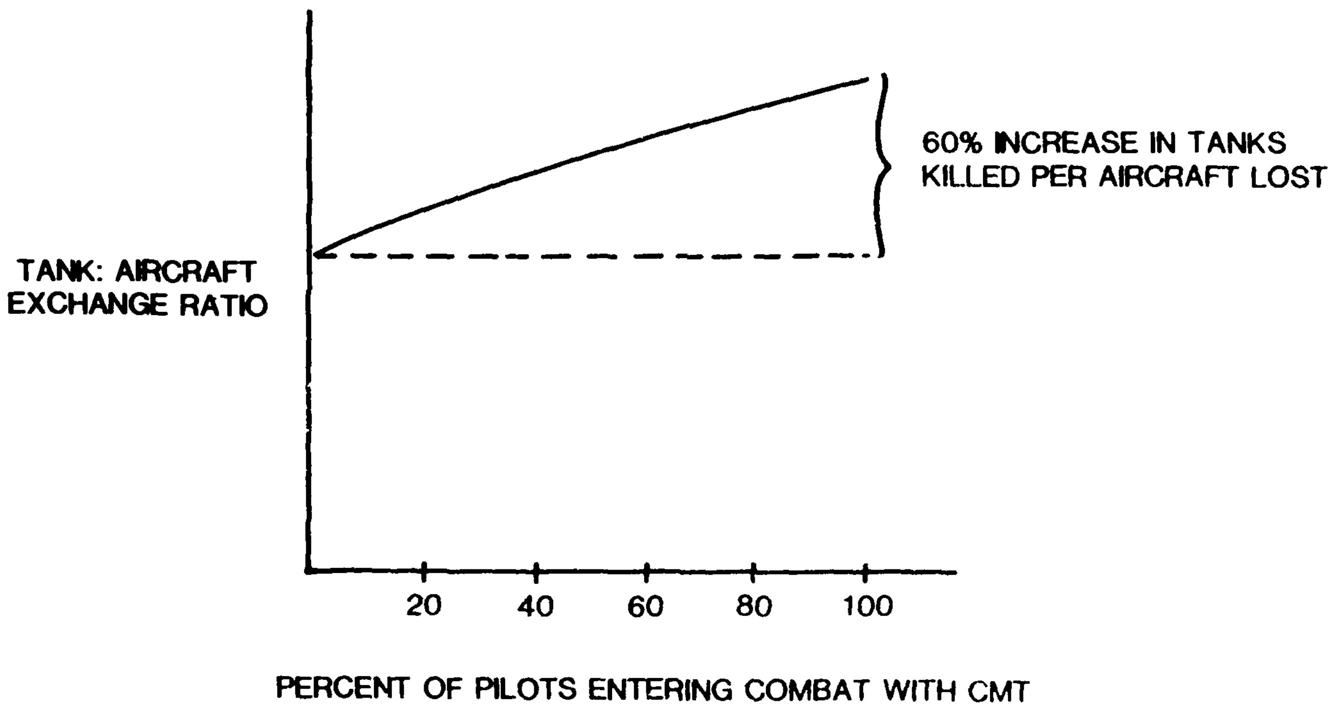
The payoff in terms of combat outcome—i.e., in terms of additional tanks destroyed—as a function of the percentage of the aircrews who enter combat with the experience of 10 training/combat encounters, is impressive. It argues strongly for such training being potentially quite beneficial. The benefits would be realized, of course, only were the armed conflict to occur.


PAYOFF IN TERMS OF COMBAT OUTCOME
ADDITIONAL TANKS KILLED
20
40
60
80
100
PERCENT OF PILOTS ENTERING COMBAT TRAINED IN CMT

The payoff of such CMT (or equivalent) training for the close air support (CAS) mission in terms of the tank-to-aircraft exchange ratio is also quite impressive. It is nearly linear and shows a 60 percent increase in enemy tanks killed per friendly aircraft lost were all "Blue" aircrews to enter combat with the skills trainable in 10 training/combat encounters.

PAYOFF OF CMT FOR CAS MISSION

(FIRST FOUR DAYS OF COMBAT)



With these new "experience" parameters, let's now rerun the European combat model that we used for the baseline table. Then let's compute the aircraft remaining after each of the ordinal days of conflict and present the data as a new row added to the baseline table. For these notional computations, I have used a predicted loss rate of .40 for the Blue-force Day-1 and halved that rate daily to .025 on Day-5 and subsequently. For the Blue force with CMT training, I have used a very conservative (*and credible*) predicted loss rate of .10 on Day-1, .05 on Day-2, and .025 on Day-3 and subsequently. That is to say, I have assumed that the CMT *training provides the experience* equivalent of the initial 2 days of combat. In both cases, I have assumed a steady-state situation; that is to say, I have made no adjustments for *replacement* of lost aircrews or aircraft. Such adjustments would further favor the CMT-*training* condition.

Under the assumptions I have made, the results indicate that with CMT-combat trained aircrews, there would be about twice as many aircrews and aircraft remaining on the fourth and subsequent days of the conflict. Put another way, in order to have an equivalent number of aircrews and aircraft remaining on the fourth and subsequent days of conflict without the CMT-combat training, we *would have had to* start on Day-0 with twice the force that we have, however many that may be. Put yet another way, were we *to be successful* in our proposed *development of a state-of-the-art* CMT, which though transportable and less expensive than the ASPT provides no more effective training than that already demonstrated, the Air Force would have the potential of doubling the fourth-day-and-beyond effectiveness of whatever force it has.

This speaks credibly and quantitatively about the potential *impact of providing appropriate training* in air combat tactics with simulation, but it falls short of being a convincing argument for the Air Force supporting the proposed CMT *development. What* is needed is a look at the alternative ways of achieving the same result and the relative costs of those alternatives.

AIRCRAFT REMAINING

FORCE	END OF CONFLICT-DAY 1	2	3	4 . . . n
RED	i_1	i_2	i_3	$i_4 \dots i_n$
BLUE	j_1	j_2	j_3	$j_4 \dots j_n$
BLUE: W/CMT TNG*	$150 j_1$	$1.78 j_2$	$1.93 j_3$	$1.98 j_4 \dots 1.98 j_n$

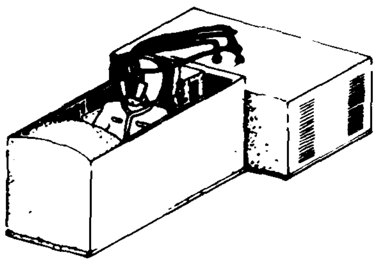
*LOSS RATE ON DAY X ASSUMED EQUAL TO BLUE LOSS RATE ON DAY X+2. STEADY STATE ASSUMED — NO REPLACEMENT AIRCREWS OR AIRCRAFT.

For purposes of simplicity, let us assume that the major alternatives are the proposed CMT and the conventional ASPT-type simulator, either dome or mosaic-CRT. Let us also assume that the costs—development, acquisition, ownership, and 15-year life-cycle—are *identical* for all types of conventional devices, whether dome or mosaic. Relative to the conventional, the CMT devices we shall assume to cost 10 times more to develop, but 10 times less to acquire, and 5 times less to own. Depending on the numbers of simulators required, the 15-year life cycle costs can then be computed.

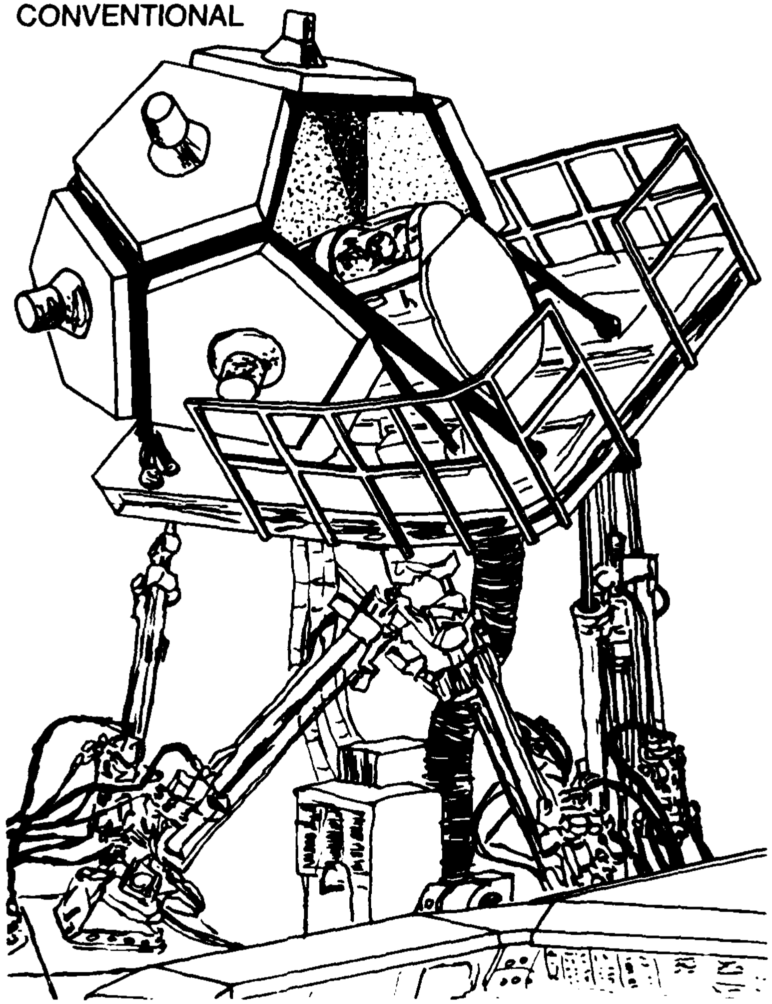
To compute the numbers needed, let's assume that the available behavioral data on air combat training permit us to estimate that it takes K trials for aircrews to acquire the desired skills on the average (to the levels assumed in the model), and that it takes L retraining trials per M weeks to maintain those skills. Then, since we know the *numbers of aircrews per squadron and per wing*, and the numbers of hours of simulator availability for such training, we could compute the numbers of CMT or conventional simulators required.

CMT ADVANTAGE : SUPPORT FACILITY COST

CMT



CONVENTIONAL



We have *not* computed those numbers for presentation here, so I can present only the notional form of the table of comparisons of the training/simulator options. However, using "D" for the development costs, "A" for the acquisition, and "O" for the ownership costs of the conventional (*dome or mosaic*) simulators, and the indicated relative costs of the CMT, we can present the way in which we would compute the cost data.

We have already presented the benefits in terms of the aircraft remaining on the fourth and subsequent days of conflict; the use of either simulator produces a two-to-one advantage over using neither. In terms of outcome of the combat, whatever the probability of a win is with use of the simulators, it is less without their use.

Cost/effectiveness ratios have not been computed, nor could they be unless the outcome probabilities were first stipulated (cost/effectiveness is meaningful only under a "win" condition—*it is meaningless* when the war is lost). Depending on the level of that outcome probability, the cost/effectiveness of the "neither" condition may be meaningless. Since the other two options (the conventional and CMT simulators) have the same outcomes and benefits, the cost/effectiveness ratios would be equivalent to the cost ratios, and these cannot be stated without specific values assigned to "D," "A," and "O."

COMPARISON OF TRAINING/SIM OPTIONS

	OPTIONS		
	CONVENTIONAL	CMT	NEITHER
COSTS			
DEVELOPMENT	D	10D	-0-
ACQUISITION	A	$10^{-1}A$	-0-
OWNERSHIP	O	$5^{-1}O$	-0-
15-YR. LCC	(D+A+150)	$(10D+\frac{A}{10}+30)$	-0-
BENEFITS			
AIRCRAFT (4^{th} DAY)	$1.98j_4$	$1.98j_4$	j_4
OUTCOME	P(win)=W	P(win)=W	P(win)<W
COST-EFFECT			
RATIO	—	—	—

The mission of AFHRL in its area, like that of the other AFSC Laboratories in their areas, is to develop the technology base through R&D the findings of which can be employed to provide Air Force management—the Air Staff, MAJCOMs, operational field commanders—with options through which *they* can increase the ease and probability of air combat success.

The notional CMT impact analysis presented here is meant to show just how we should go about presenting our options for R&D to Air Force management. If, given the results as we have developed them, our management elects not to support our proposed efforts with funds and resources, we should be very happy indeed for that would mean they have something that promises to be even more beneficial than an effective doubling of the air combat force *on the fourth* and *subsequent* days of *armed* conflict. If they have something better in which to invest Air Force R&D funds, then I, too, would favor it. I, too, want us *to win* in any conflict we may be forced to enter.

Thank you.